

Development of Model for Coastal Waves and Floating Structures

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LONG-TERM GOAL

Our long-term goal is to develop a comprehensive model to predict coastal surface waves in any harbor (or open coastal regions also) and their effect on floating objects in confined waters. Several years of theoretical and applied research will be converted into a practical tool that eliminates the limitations of existing nearshore wave models used operationally by the Navy.

OBJECTIVES

Our objectives are to further develop and provide to the Navy a wave transformation model that includes wave refraction, diffraction (by bathymetry and structures, islands, etc.), reflection, dissipation by friction and breaking, and the effect of tidal (or other surface currents) on wind waves and swell. The goal is to make the model simultaneously accurate (to obtain a satisfactorily reliable representation of the sea-state) and efficient (for rapid integration with other ocean wave models and/or possible onboard utilization with a medium-size computer). A further goal is to develop a three-dimensional module (to be interfaced with the wave model) that can utilize the predicted wave fields to estimate forces on floating structures in a harbor.

APPROACH

The base model is a 2-dimensional finite element elliptic combined refraction-diffraction model, also known as the mild-slope wave equation, that describes the propagation of water waves over an arbitrarily varying sea-bed for the full spectrum of practical wave conditions, irrespective of wave directions and domain shape. We had developed this model previously. Most of the current work involves development of modeling techniques and code modifications to enhance the versatility, reliability, and efficiency of the model. These include incorporation of new features like improved open and coastal boundary conditions, dissipation mechanisms (breaking and friction), wave-current interaction, faster solution techniques, and field validation.

WORK COMPLETED

(a) Improving the treatment of open boundaries. Existing models of this category are based on the assumption that the domain exterior of the model domain is of constant depth. This assumption leads to inaccurate predictions. We have constructed a new treatment for the open boundaries based on the assumption that the exterior region can be represented by two one-dimensional sections, one on either side of the model domain, with depth varying in the offshore direction. This is far more realistic for

many applications. This is ready for operational use.

(b) Improving the treatment of coastal boundaries. Existing coastal boundary conditions are accurate only for waves approaching the boundary in a normal direction (for arbitrary reflectivities). We have developed a new nonlinear boundary condition for all angles of wave approach at the internal boundaries. The basic method has been developed and checked, but it is not yet operational. The method of estimating wave angles in this context should also help (h) below.

(c) Improving the speed of model operation. Model iterations can be very time-intensive for spectral simulations. Code-related issues were addressed, in concert with Dr. Demirbilek and the High Performance Computing staff at the Army WES, to develop a version of the model suitable for parallel processors. For the Army's CERC shoal test, spectral simulations with 75 components on a domain with 30,000 grids were performed in 2 hours. Similarly, issues pertaining to grid construction and graphics were addressed to improve enhance the efficiency of model operation. Both developments have been implemented in operational versions. We are also investigating other iterative schemes (such as the Generalized Minimum Residual Method and the Biconjugate Gradient Method).

(d) Improving the physics being modelled. We developed wave breaking algorithms (based on the formulations provided earlier by Dally et al.(1985) and Battjes and Jansen (1978)) and spatially varying dissipation algorithms for simulating bottom friction and harbor entrance losses. Wave breaking and constant dissipation are now operational (but not yet with the new boundary conditions).

(e) Validation. Preliminary simulations of waves in Ponce de Leon Inlet and near FRF Duck were performed.

(f) Basic formulations and code development for the 3d simulations including floating objects, based on the boundary integral equation method.

(g) A technical manual and user instructions with test-cases were prepared, describing the current model (to be published by the Army WES).

(h) Wave-current interaction: will be tackled. This involves modifying the governing equation, as described by Kirby (1984). The difficulty here is the requirement of wave angles, but our development in (b) should be of great help.

RESULTS

As noted above, many improvements have been implemented in the currently operational version. Space permits the demonstration of only a few results. All of these results are not obtained by any single existing model, demonstrating the model's comprehensive nature.

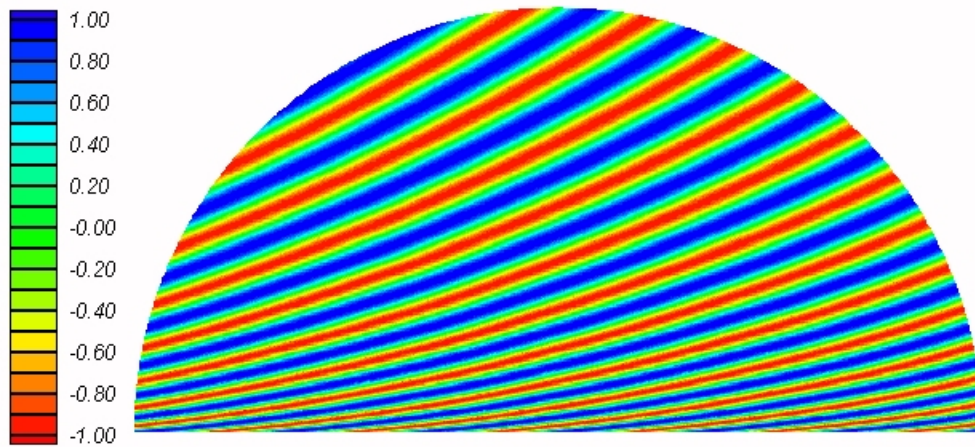


Figure 1. Simulation of short waves on plane sloping beach. Phase diagram. Expected bending of wave rays is observed. Incident wave angle is 60 degrees from normal at 3 km offshore. Incident wave period is 6 seconds. Length of the coastline is 6 km.

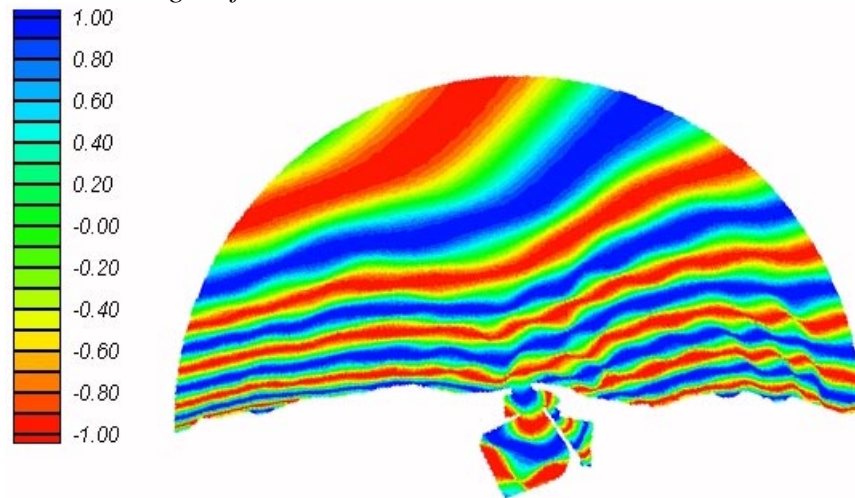


Figure 2. Simulation of waves in Barber's Point Harbor, Hawaii. Phase diagram. Previous models contained spurious reflections from inappropriate open boundary treatment. Incident wave angle is 60 degrees from normal at 6 km offshore. Incident wave period is 50 seconds. Coastline length is approximately 6 km.

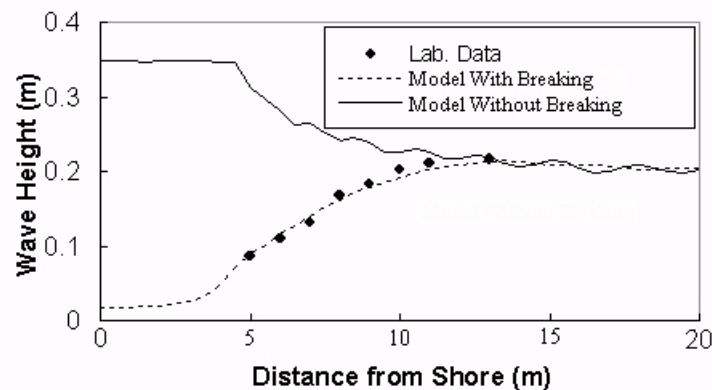


Figure 3. Simulation of wave breaking, Battjes & Jansen (1978) lab study. Waves are running up a slope from right to left.

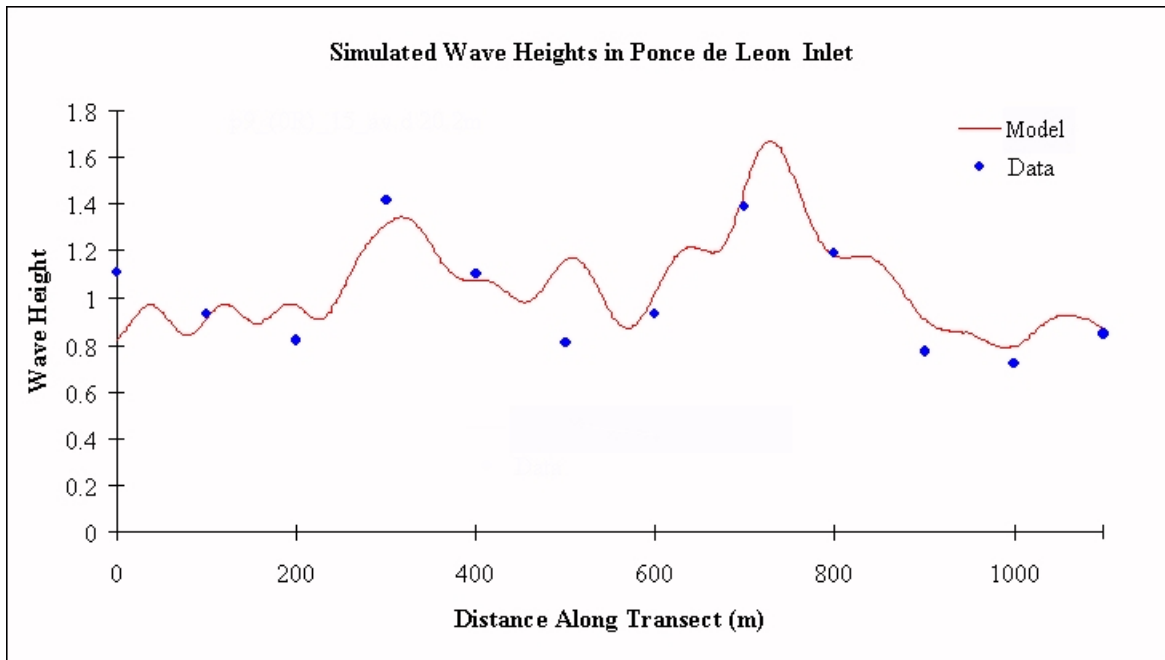


Figure 4. Ponce de Leon inlet, Florida. Model results and data shown for a longshore transect.

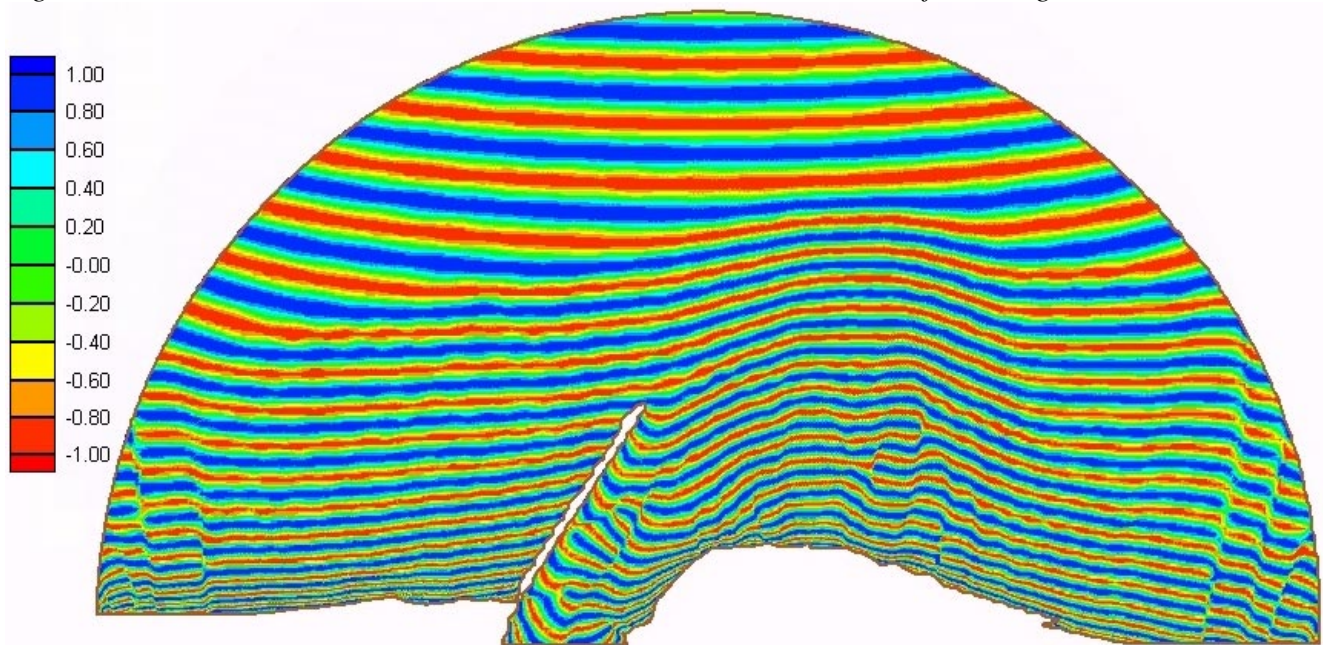


Figure 5. Simulation of waves in Ponce Inlet. Phase diagram. Normal incident, 15 second waves. Coastline length is approximately 4.8 km.

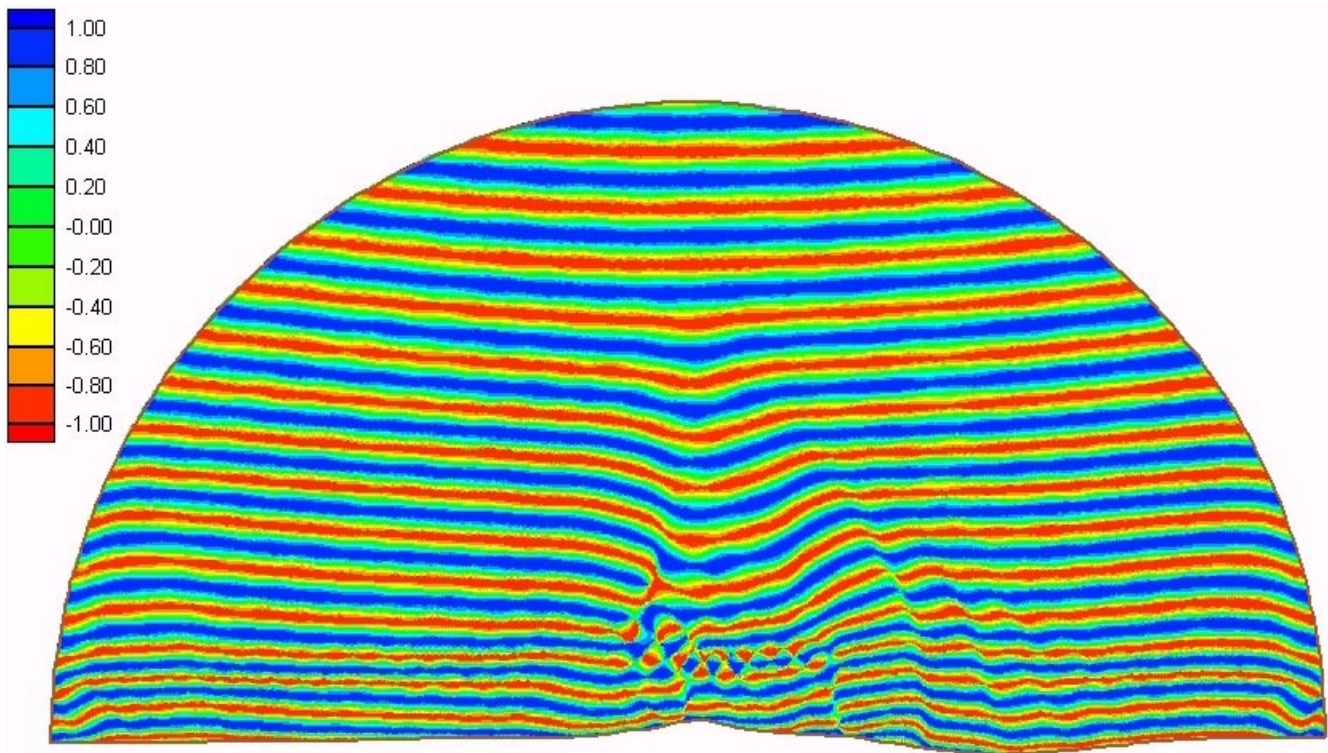


Figure 6. Preliminary simulation of waves at FRF, Duck. Normal incident, 8 second waves. Coastline length is approximately 1.5 km.

IMPACT/APPLICATIONS

The model that is gradually being enhanced will provide the Navy with perhaps the most sophisticated model for predicting waves in coastal regions such as harbors, which have arbitrary shapes and depths. The second module will enable estimation of wave forces on structures such as ships, LCAC's, etc. These predictions, if obtained with reliability and efficiency, may influence naval operations such as amphibious or loading and unloading activities. From a civilian perspective, the model can be used by the Army Corps of Engineers in harbor design activities.

TRANSITIONS

We are working with Dr. Demirbilek of the Army WES in transferring this technology to other DoD users, mainly because of his expertise and his proximity to DoD personnel in Stennis Space Center. A recent version of the model has been transitioned to Dr. Demirbilek. As noted earlier, a manual was prepared, largely per DoD needs indicated by Dr. Demirbilek. Dr. Demirbilek visited the University of Maine for 2 weeks to work with me and my students and learn intricacies of the code. He then conducted a 2-day workshop involving training in the use of the model in September 1998 for Army Corps and Navy personnel. (Unfortunately, a hurricane at that time prevented greater attendance). Dr. James Dykes of NAVO attended. Dr. Larry Hsu of NAVO, whose plans to attend were disrupted by the hurricane, has an older version of the model. He will shortly receive a more recent version. Additional workshops are being planned. Dr. Demirbilek has been instrumental in guiding our model development to suit DoD needs.

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PUBLICATIONS

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